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SYSTEM OF ECONOMIC PLANNING EXAMINED

Moscow EKONOMIKA I MATEMATICHESKIYE METODY in Russian No 5, Sep-Oct 79 pp 902-912

[Article by S. V. Kazantsev (Novosibirsk) "The Macroeconomic Model of the System of National Economic Indicators"]

[Text] In 1966 there was advanced one of the concepts[1] for the building of a system of economic-mathematical models based on the idea of the national economy as a complex hierarchal system. This approach enables us to employ various levels for analysis of, planning and programming of the economic development of the model: national economic levels, sectorial levels, regional levels, etc. Each level is characterized by its own set of the indicators to be used and by the degree of disaggregation as determined by the nature of the task.

Comprising one of the elements of the subsystem of models of the upper level are the macroeconomic models which employ integrated indicators such as aggregate national product, national income, productive capital, number of workers employed in physical production, indicators of capital-output ratio and labor intensiveness of production, and volume of foreign trade balance. Despite the fact that macroeconomic models have been in use for a long time, the possibilities for their use in economic analysis and forecasting have by no means been exhausted. These models can find practical application in the initial stages of the construction of forecasts of the comparatively distant future, when it is necessary to substantiate only the general principles and trends pertaining to the overall national economic indicators. In average time-period forecasting the macromodels can be used for the general elaboration of the concepts of national economy development without examining the concept in its sectorial and territorial aspects. In Gosplan USSR macroeconomic models were used to solve problems which arose back in the period of preparation of the first five-year plan.[2,3]

The operational calculations compiled in the Institute of Economics [IE] and the Organization of Industrial Production [OPP] of the SO [Siberian Department] of the AN [Academy of Sciences] USSR in the 1973-1977 period showed that in the variant calculations it is desirable to employ the

following method of establishing the relationship between the macromodel and the disaggregate models: First, on the basis of the macroeconomic models, the researcher defines and evaluates the variants of possible economic growth and selects from them the ones which should in the future be analyzed with the help of the disaggregated models. Second, the macroeconomic models can be used as auxiliary tools for studying the process of calculations based on the disaggregated models: they are used for rapid checking and quantitative evaluation of the assumptions and hypotheses concerning the growth variants which emerge in the course of the calculations based on the disaggregated models, for determining the behavior of the global national economic indicators in the planning period, and for making the calculations which explain the mechanism for obtaining the various results from the computations based on the disaggregated models.

Formalized Description of the Scheme of Material and Physical Relationships of Socialist Reproduction

Because of the limited scope of the indicators used, most of the macroeconomic models do not permit describing and analyzing many of the important national economic relationships such as, for example, the effect of the output-capital ratio, the production materials consumption, and the norms of production accumulation on the relationship between subdivisions I and II of national production; the effect of the distribution of the capital investments on the expansion and replenishment of fixed production capital; the effect of dividing the fixed production capital accumulation on the accumulation from national income and the accumulation from amortization; the division of amortization into the segment for replacement of retired capital and the segment earmarked for accumulation. To construct a model describing the whole system of relationships of the macroeconomic indicators it is necessary to enlarge the number of these indicators in comparison with the usual number considered. The proposed model includes all the indicators which require analysis in the course of the estimates compiled in the IE and the OPP of the SO of AN USSR with respect to the long-term prospects for the development of the country's economy.* At the same time, we assigned the goal of imparting an applied character to the model and hence the principles underlying the compilation of the indicators in it are based on the methodology for the calculation of them in the theory and practice of national economic planning.

*The calculations were made for a group of models, which, in addition to the proposed one, includes a linear optimization intersectorial model and a consolidated dynamic multisector model (For more details on these models see [Bibliography] 4-6.

The following symbols were adopted in the model: L*--the number employed in physical production; X--gross national product; C--physical input; s*--amount of the foreign trade balance and losses; U--end product; $Y^{(1)}$--national income produced; Y--National Income used; X^{I}--output of subdivision I of national production; X^{II}--output of subdivision II; B--reimbursement fund; Φ --fixed production capital at the end of the year; $\Delta\Phi$--increase of fixed production capital; K--production capital investments; R--fixed capital retired; V--fixed production capital put into operation; ∇ --increase of unfinished capital investments: D--amount of amortization of fixed production capital; $N^{(D)}$--accumulation of fixed production capital through amortization; $N^{(y)}$--accumulation of fixed production capital through national income; N--volume of production accumulation; Δ M*--increase of physical input, stocks and reserves (less increase of unfinished capital investments); p--labor productivity in terms of gross product; b*--output-capital ratio; k*--capital-labor ratio; c--materials expended for gross product; m*--proportion of physical input and increase of stocks and reserves in gross national product; r*--percent of retirement of fixed production capital; $0 < r \leq d$; d*--norm of amortization of productive capital, $0 < d < 1$, n--norm of production accumulation; $n^{(1)}$--norm of accumulation of fixed production capital; l*--ratio of increase of unfinished capital investments to fixed capital put into operation; t--time index.

The actual values of the parameters of the model in the base year are determined according to the statistical yearbooks in accordance with [bibliography] 7. For the purpose of exogenous calculations changes have been made in nine parameters (in the list of symbols they are indicated by an asterisk), following which a system of equations is solved for each year t successively.

$$\Phi(t)=L(t)k(t), \quad (1)$$

$$X(t)=\Phi(t)b(t), \quad (2)$$

$$\Delta\Phi(t)=\Phi(t)-\Phi(t-1), \quad (3)$$

$$R(t)=\Phi(t-1)r(t)/100\%, \quad (4)$$

$$D(t)=\Phi(t-1)dt/100\%, \quad (5)$$

$$V(t)=R(t)+\Delta\Phi(t), \quad (6)$$

$$N^{(D)}(t)=D(t)-R(t), \quad (7)$$

$$N^{(Y)}(t)=\Delta\Phi(t)-N^{(D)}(t), \quad (8)$$

$$\nabla(t)=V(t)l(t), \quad (9)$$

$$K(t)=V(t)+\nabla(t), \quad (10)$$

$$M(t)=X(t)m(t), \quad (11)$$

$$C(t)=M(t)-\Delta M(t), \quad (12)$$

$$U(t)=X(t)-C(t)-s(t), \tag{13}$$

$$Y(t)=U(t)-D(t), \tag{14}$$

$$Y^{(1)}(t)=Y(t)+s(t), \tag{15}$$

$$X^{I}(t)=M(t)+K(t), \tag{16}$$

$$X^{II}(t)=X(t)-X^{I}(t)-s(t), \tag{17}$$

$$N(t)=Y(t)-X^{II}(t), \tag{18}$$

$$B(t)=C(t)+D(t), \tag{19}$$

$$p(t)=k(t)b(t), \tag{20}$$

$$c(t)=C(t)/X(t), \tag{21}$$

$$n(t)=N(t)100\%/Y(t), \tag{22}$$

$$n^{(1)}(t)=N^{(Y)}(t)100\%/Y(t). \tag{23}$$

Simplifying assumptions have been adopted in the model.

1. Fixed production capital is introduced instantaneously at the beginning of the year. This assumption is easily withdrawn and coefficients are introduced for transfer of the capital on the date into average yearly capital and for uniformity of the transfer of capital.

2. There is no lag for capital investments put into operation. To date, no decision has been reached on the methods of showing their time structure in the models; in the statistical record work and the planning calculations the production capital investments are linked with the indicators for volume of fixed production capital put into operation either as an equation (10) or by the correlation $\omega(t)K(t)=V(t)$, where ω designates the coefficient for putting productive capital into operation.

3. The volume of fixed production capital does not decrease in time, i.e., the rate of growth of capital is $\rho \geqslant 1$. This assumption is in keeping with the nature of the development of Soviet economics in the period of peaceful construction and in the model indicates that all the retired capital is being replaced. In the accounting work this leads to a limiting of the selection of rates of growth of the number employed in physical production L and the capital-labor ratio $kL \geqslant 1$ since $kL=\rho$.

Limitations are also placed on the size of parameter l

$$\max\left\{-1,-\frac{N(t)+\Delta M(t)}{N^{(Y)}(t)+R(t)}\right\}<l(t)<1$$

Going beyond these limits will entail obtaining in the model a negative value for the volume of production capital investments and production accumulation (See equations (6), (9) - (14) and (16) - (18).

Use of the Model for Analysis of Economic Growth

In analysis of economic growth the macromodels can be used in two ways. First, to determine the consequences of a particular change in the economic growth factors; in this case we study the effect of a particular hypothesis concerning a change in the factors pertaining to the generalizing national economic indicators. For example, we evaluate the effect of reducing the rate of growth of the overall volume of capital investments on the dynamics of the aggregate national product, national income and the output of subdivision II. Second, the macromodels are used to determine what change in the level of the growth factors achieves the indicated volumes of final economic characteristics, i.e., to answer the question as to what input factors are necessary to obtain particular values of the generalizing national economic indicators. For example, the proposed model enables us to determine the growth of capital and the change in output-capital ratio necessary for achieving the assigned dynamics of national income. The variant calculations discussed below employ both courses in the use of the macromodels in analysis of economic growth.*

The decisive factor in long-term economic growth is labor productivity. In the model this indicator appears as a strictly endogenous quantity which is determined by the product of the capital-labor ratio and the productive-capital yield. In the assigned dynamics of the yield on capital the rate of growth of labor productivity is determined by the growth of its capital-labor ratio, which is dependent on capital investments.

A detailed analysis of the problems of economic growth, including the sectorial and territorial structure of the capital investments, cannot be made just on the basis of the macroeconomic model. The proposed model can be used to solve the narrower problems: analysis of the variants of capital investment policy in respect to their total volume and on the scale of the national economy as a whole under several hypotheses concerning change in the number of workers employed in physical production, labor productivity, materials expenditure in production, and yield of fixed production capital.

Forecasting of the dynamics of worker numerical strength is a task of specialized research (See, for example, [bibligraphy] 8, pp 171-188). The procedure adopted in the variant calculations calls for leaving the worker numerical strength unchanged in the first of the three periods reviewed, reducing it by .5 percent yearly in the second period, and increasing it by .5 percent in the third period.

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*The variant of the program of computations was compiled and issued for printing by Z. M. Tkalich for all the years of the period and by A. V. Shcherbinskiy for just the assigned years (the "Alpha" language was used).

The proportion of physical input and the increase of stocks and reserves (not counting the increase of unfinished capital investments) in gross national product as a whole rose in the 1961-1970 period and declined somewhat in the 1971-1975 period. The decisions of the 25th CPSU Congress provide for further reduction of the expenditures of raw material and materials per unit of output. In accordance with these decisions a hypothesis was adopted in the accounting calling for a reduction of materials expenditures: The expectation is that the proportion of physical input and increase of stocks and reserves (not counting increase in unfinished capital investments) in gross product will decline by .1 percent a year (such were the dynamics of this indicator in the Ninth Five-Year Plan).

Since 1954 the output-capital ratio has been declining in the national economy. A number of factors contributed to this. They include increased capital-output ratio in agricultural production, mechanization of auxiliary operations in all the sectors of the national economy, the progress of construction in the eastern, northern and nearly inaccessible regions, and the increasing expenditures of fixed production capital as a result of the decline in the quality of the raw material resources. It is very likely that these factors will continue to be operative. The decline in output-capital ratio will apparently not cease, at least before we accomplish the task of implementing a significant reduction in the proportion of manual labor and the number of workers employed in agriculture. Consequently, all the accounting variants provide for a reduction in the output-capital ratio. The rate of reduction has been pegged at 2.5 percent yearly, which is in keeping with the dynamics of our country's yield on capital in the last 10 years.

The rates of growth of capital-labor ratio is set as a variable control and is assigned for each specific variant of the calculations (See Table 1 below). The other exogenous parameters of the model are constant in all the variants.

Table 1

Rates of Increase of the Capital-Labor Ratio in the Experimental Calculations, percents

	Variants			
Periods	1	2	3	4
1	106.4	107.2	106.1	107.0
2	106.4	107.8	105.8	108.2
3	106.4	106.7	104.3	108.3

Variant 1 provides for constant rates of growth of labor productivity. The figures indicate that, when all other conditions are equal, there is need for an increase in the rates of growth of capital investments (Table 2 below). Appearing as a significant factor bearing upon the requisite volumes of capital investments are the dynamics of the worker numerical strength and the capital-output ratio in production. Stabilization or reduction of worker strength will lead to a denial of capital investments for the establishment of new jobs for an additional number of workers. However, maintenance of stable rates of growth of labor productivity when the level of capital-output ratio is declining requires capital investments which will insure growth of the capital-labor ratio. The volume of capital investments required increases along with the capital-labor ratio and the reduction in yield on capital. If we add to these factors an increase in the number of workers employed in the national economy, as anticipated for the third period, then the rates of growth of capital investments will increase sharply and they will need to be implemented on a large scale.

Table 2

(1) Расчетные среднегодовые темпы роста некоторых макроэкономических показателей, %

(4) Показатель	(2) Варианты: 1			2			3			4		
(3) периоды	1	2	3	1	2	3	1	2	3	1	2	3
(5) Валовой общественный продукт	104,8	104,2	105,3	105,6	105,6	105,6	104,5	103,7	103,2	105,4	106	107,2
(6) Национальный доход, использованный на потребление и накопление	104,6	104,1	105,1	105,4	105,4	105,4	104,3	103,4	103	105,2	105,9	107
(7) I подразделение общественного производства	104,5	104,3	106	105,6	105,8	105,8	[illegible]	103,7	103,3	105,2	106,4	107,7
(8) II подразделение общественного производства	105,3	104,1	104,1	105,6	105,2	105,2	105,2	103,7	103,1	105,6	105,3	106,1
(9) Суммарные производственные капитальные вложения	103,7	105,4	109,2	[illegible]	[illegible]	107,3	102,7	104,2	104,3	105,4	108,7	110,1
(10) Производительность труда в расчете по валовому продукту	104,8	104,8	104,8	105,6	106,1	105	104,5	104,2	102,7	105,4	106,6	106,7
(11) использованному национальному доходу	104,6	104,6	104,6	105,4	105,9	104,8	104,3	104	102,5	102,5	106,4	106,4

Key:

1. Estimated average yearly rates of some macroeconomic indicators, percents
2. Variants
3. Periods
4. Indicator
5. Gross national product
6. National income used for consumption and accumulation
7. Subdivision I of national production
8. Subdivision II of national production
9. Overall production capital investments
10. Labor productivity per gross product
11. Labor productivity per national income used

Variant 2 was compiled to show what capital investments will make possible a stable increase of national economy output at a level of approximately 5-6 percent increase a year. The reduction in worker strength is counteracted by accelerated growth of labor productivity. In the third period there is some reduction in the rates of growth of labor productivity because it is assumed that the number of workers will increase without accelerated growth of production of output. Since the hypotheses concerning change of all the exogenously assigned parameters (except for the yield on capital) is here the same as in the first variant, the result is an evaluation of the interrelationship between the additional growth of labor productivity and the capital investments. The overall volume of capital investments in the third period in Variant 2 is 22 percent more than in Variant 1. Additional capital investments produce more rapid rates of growth of labor productivity and as a result the level of productivity in the subsequent year of the period in Variant 2 is 19 percent higher than in Variant 1 and the volume of the output of subdivision 2 is 18 percent more.

Variant 3 illustrates the consequences of a reduction in the rates of growth of capital investments, a reduction which caused a slowdown in the growth of labor productivity. This in turn was a decisive factor in the overall reduction of the rates of economic growth in this variant. The volume of the national income generated is regularly lower than in the preceding variants. In the last year of the period under review the difference comes to 16 percent as compared to Variant 1 and 29 percent as compared to Variant 2. The output volume of subdivision 2 is also considerably lower and by the end of the period will come to 9 and 23 percent respectively. The fact that the rates of growth of output in subdivision II exceed the amounts of national income used is due to the rejection of accumulation and the redistribution of national income in favor of consumption (the norm of accumulation of fixed production capital has dropped from 11 to 4 percent in this variant). The increase in the number of workers employed in the last period required the diversion of funds for the establishment of new jobs and resulted in a corresponding reduction in the growth of output in subdivision II. Variant 3 shows clearly that if measures are not taken simultaneously for increased production efficiency, the policy of reducing the rates of growth of capital investments will inevitably lead to a slowdown in economic growth and goes counter to achievement of the aim of the socialist method of production. The dynamics of economic development can be radically different if we adopt a course of increased effectiveness of the national economy and take a decisive step in the direction of intensification of national production. Other conditions being equal, acceleration of the rates of economic growth is indissolubly linked with stepped up rates of the growth of capital investments. These accelerated rates are associated with a significant restructuring of the national economy, require a considerable length of time for their implementation, and need preparation at the proper time. However, the acceleration of the rates of growth of capital investments in a stated period of time may not be as great as desired. Under these circumstances when there is a constant or declining output-capital ratio in the final time

period, there arise rather rigid limitations on any increase in the capital investments and consequent growth of labor productivity which are determined by social planning factors. Such limits are set for relatively short periods but can be adjusted to longer periods. Thus, from the standpoint of enhanced public welfare not only is a reduction in the rates of growth of capital investments an ineffective course of action, but also so is a very rapid growth of these investments.

The upper limit of capital investments within the assumed hypotheses is approximately indicated by Variant 4. The calculations for it illustrate what growth of national production can be obtained with an acceleration of up to 9-10 percent in the increase of capital investments. This also retains the hypothesis concerning reduction of the yield of fixed production capital. The stepped up rates of growth of capital investments in the variant under review will lead to an acceleration of the increase of labor productivity and national income. However, a sharp increase in the volumes of capital investments will bring about a situation where nearly all the additional national income obtained from the stepped up labor productivity will go into the production accumulation. When the overall volume of capital investments is increased by 13 percent in Variant 4 as compared to Variant 2, then the volume of the output of subdivision 11 in the final year will be only 5 percent greater (See Table 3).

Table 3

Increase of Labor Productivity, Volume of Output of Subdivision II, and Overall Capital Investments in Variants 2 and 4 (in percents)

Indicator	Value of the Indicator in the Final Year of the Accounting: Variant 2 in percents of Variant 1	Variant 4 in percents of Variant 2
Overall volume of capital investments	124	113
Labor productivity	120	111
Volume of Output of Subdivision II	118	105

Variant 4 also shows that the dynamics of the generalizing national economy indicators are determined not only by the possibilities for implementing the capital investments but also to a considerable degree by the change in the materials expenditure and the capital-output ratio. The decline in the effectiveness of capital investments observed in the accounting is the direct result of the reduction in yield of the fixed production capital and the lack of a substantial reduction of the relative physical input. In the context of technical progress in which the growth of productivity proceeds

when there is a decline in output-capital ratio and no reduction in input of materials, a decrease in the effectiveness of investments is inevitable. Switching to the new type of technical progress with its substantial reduction of input of materials and increased yield of assets not only makes possible acceleration of the rates of production but also raises the upper limit of the socially effective rates of increase of capital investments.

Table 2 points up the dynamics of subdivisions I and II of national production. In all the variants, with the exception of No 2, the development of subdivision II outstrips the development of No 1. This is due to the fact that the conventional accounting for variants 1, 3 and 4 results in a reduction in the rates of growth of fixed production capital in comparison with the base year. The reduction was 1.5, 2 and 1 point respectively and led to a sharp decline in the growth of fixed production capital in relation to the base year. Thus, in the first period this indicator for Variant 1 declined by 11 percent, which caused a reduction in the amount of fixed production capital put into operation and brought about a decline in the rates of growth of subdivision I as a whole. Also contributing to this was some falling off of the input of materials. In the model under review gross national product breaks down to a fund for replacement of production resources expended and to production accumulation and input and is not fed by these sources. Consequently, a change in the proportion of physical input in the gross product affects only the volume of production of output of subdivision I but does not affect the amount of the gross product. In the subsequent periods the effect of the reduction if input of materials was covered by an increase in the fixed production capital and a reduction of their yield.

The calculations enabled us to make a quantitative evaluation of the effect of a change in the rates of growth of fixed production capital, its yield, and the physical input of production materials on the dynamics of national production subdivisions I and II. The nature of the effect of these factors on the growth of the two subdivisions can be determined by a conventional method. Actually, using equations (11) and (16) we get:

$$X^1(t)/X(t) = K(t)/X(t) + m(t).$$

It can easily be seen that the derivative $X^{(i)}(t)/X(t)$ for the rate of growth of fixed production capital ρ is equal to

$$[1 + l(t)] \quad [1 - r(t)]/b(t)\rho 2 > 0.$$

The derivative is positive and consequently the proportion of output of subdivision I in the aggregate national product goes down when the rate of growth of fixed production capital declines; this means faster development for subdivision II. Reduction of the output-capital ratio contributes in the model to more rapid growth of subdivision I.

$$\left(\frac{X^{I}(t)}{X(t)}\right)_{t}^{1} = -\frac{\rho - 1 - r(t)}{\mu c(t)^{2}}[1 - l(t)] < 0^{*}.$$

It can readily be seen that in this direction entails an increase in input of production materials.

We note in conclusion that the calculations made do not take into account the relationship between fixed production capital replacement and the level of its yield. The yield on capital investments (new) made in the accounting year is taken as equal to the yield from active (old) capital. In reality, it turns out that the yields from new and old capital are different. The interrelationship between the output-capital ratios for new and old capital can be accurately represented in the following manner.

Assume that at the beginning of the year t the economic system had capital in the amount of $\Phi(t)$ and this capital was instrumental in the production of output amounting to $X(t) = \Phi(t)bc(t)$, where $bc(t)$ is the capital yield in the year t. Assume that in the next year t + 1 a replacement in the amount of $R(t + 1)$ was made for part of the capital and the volume of capital $\Delta\Phi(t + 1)$ was increased. The new capital $R(t + 1) + \Delta\Phi(t + 1)$ differs from the old $\Phi(t) - R(t + 1)$ in its output-capital ratio.

$$b_h(t + 1)/bc(t + 1) = a(t + 1) \neq 1.$$

where $bc(t + 1) = b(c)(t)\beta(t + 1)$, i.e. the yield from old capital changes at a rate of $\beta(t + 1)$. Then the change in average output-capital ratio is

$$I_b(t + 1) = \frac{X(t + 1)}{\Phi(t + 1)} \Bigg/ \frac{X(t)}{\Phi(t)} = \frac{X(t + 1)}{\Phi(t + 1)} \Bigg/ b_c(t). \qquad (25)$$

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*The formula cited is correct only when "the other circumstances are equal," i.e., when the dynamics of all the factors, except output-capital ratio, are assigned. In the case of a simultaneous change in the rates of growth of the capital and its yield (with a constant material input), as was shown in [o, ch4], the following takes place. In the context of stable and rising rates of growth of capital a reduction in output-capital ratio is accompanied by an increase in the gap between the rates of the two subdivisions. Also, the greater the drop in output-capital ratio the more rapid the increase in rates of growth of the fixed production capital. When the rates of growth of fixed capital decline the drop in output-capital ratio has only a very slight effect on the gap between subdivisions I and II. Moreover, when the rates of growth of capital decline, within certain limits the reduction in output-capital ratio is even accompanied by a more rapid rate of growth of subdivision II.

The output X(t + 1) is obtained from both the new and the old capital. Part of the output obtained from the new capital can be accurately represented as the product of the new capital and its yield $[R(t+1)] + \Delta\Phi(t+1)b_h(t+1)$. Similarly, part of the output obtained on the old capital can be represented in the form of the product of the old capital and its yield $[\Phi(t) - R(t+1)]\, b_c(t)\, \beta(t+1)$. Then (25) is revised in this form.

$$I_b(t+1) = \frac{X(t+1)}{\Phi(t+1)} \Big/ b_c(t) =$$

$$= \frac{[\Phi(t) - R(t+1)]\,b_c(t)\,\beta(t+1) + [R(t+1) + \Delta\Phi(t+1)]\,b_n(t+1)}{\Phi(t+1)\,b_c(t)}$$

After making the identical changes, we find

$$I_c(t+1) = \frac{[\Phi(t+1) - R(t+1) - \Delta\Phi(t+1)]\,\beta(t+1)}{\Phi(t+1)} +$$

$$+ \frac{[R(t) + \Delta\Phi(t)]\,\alpha(t+1)\,\beta(t+1)}{\Phi(t+1)} =$$

$$= \beta(t+1)\left\{1 + \frac{R(t+1) - \Delta\Phi(t+1)}{\Phi(t+1)}\,[\alpha(t+1) - 1]\right\}$$

We will designate $\dfrac{R(t+1) - \Delta\Phi(t+1)}{\Phi(t+1)}$ through Q (t + 1). This value shows the proportion of new capital in all the capital at the beginning of the year T + 1. Thus, the change in the entire yield on capital in the year t is

$$b(t) = b_c(t)\,[1 - Q(t)] + Q(t)\,b_n(t) \qquad (27)$$

For the recorded factors t = 1, ..., T we have compiled on the basis of the relationships of (26)-(27) the system

$$b(t) = b_c(t)\,[1 - Q(t)] + Q(t)\,b_n(t).$$

$$\frac{b(t)}{b(t-1)} = \frac{b_c(t)}{b_c(t-1)}\left[1 + \frac{Q(t)\,b_n(t)}{b_c(t)} - Q(t)\right] \qquad (28)$$

System (28) contains the 2T of the equations and 2T + 1 is an unknown. The data in the official statistics enables us to compute the average indicator for the output-capital ratio and the norm for replacement of fixed production capital. If we are able to determine the output-capital ratio of old or new capital, if only for one year, then it becomes possible to calculate the dynamics of the yield of active and newly introduced capital. This will undoubtedly be of interest not only from the theoretical but also the practical standpoint.

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OPTIMAL STRUCTURE ON INTERRELATED PRODUCTION COMPLEXES

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[Article by G. V. Martynov, Moscow: "One Problem of Identifying the Optimal Structure of Interrelated Production Complexes"]

[Text] In recent years the idea of working out optimal plans for the development of complexes of interrelated production sectors has received wide dissemination. At least two reasons for this may be noted. In the first place, scientific organizations and planning agencies have accumulated considerable experience with working out and applying optimization calculations for the development and siting of particular sectors; this lays the foundation for combined optimization of several related production facilities at the same time. In the second place, under current conditions of economic development in our country increasing importance attaches to the comprehensive approach in national economic planning, raising the scientific level of plans, and attaining balanced, optimal plans.

Many works have been published recently on the problems of optimizing the development of complexes of interrelated production facilities, primarily optimization of the development of multisectorial complexes (for example see [1-10]).

In the presentation that follows the term "interrelated production complexes" will mean not only intersectorial complexes but also any other systems of production facilities considered together which can be singled out at some particular level of planning and economic management, in particular the territorial production complex, the industrial association, the association of computing and information centers, and the like. This term can be used to designate some technical systems as well. In other words, the problem considered below is to some degree invariant relative to the specific nature of the complexes.

One of the basic problems encountered when working out optimal plans of complexes is determining their structure, that is, breaking a certain given system of primary production facilities down into distinct,

non-intersecting subsystems which are comparatively independent of one another. The different aspects of this problem have been described in numerous works (for example see [11-30]). Most of them [11-26] are devoted to methods of transforming a matrix of output flows among the particular production facilities (matrix of interrelationships). These techniques are chiefly heuristic, but some of them are based on the variation approach [26]. We should also observe that the relations among production facilities are usually considered in these works only with respect to ongoing production consumption, which is one of the most important factors influencing selection of the structure of the complex. It is also important that this type of relationship be subject to quantitative evaluation. However, this is not the only factor, and when determining the structure of complexes it is necessary to take account of all factors.

These requirements are best met by another group of works (for example see [3, 27-30]) devoted to the so-called grouping problem in which each object is ordinarily characterized by a certain set of parameters and objects which are most similar for the totality of these parameters are grouped together. The techniques of automatic grouping are frequently used to solve such problems, but they do not always yield results that can be applied in practice.

This article reviews one of the possible approaches to constructing the optimal structure of interrelated production complexes with a certain limited set of mutually exclusive alternatives planned in advance to join these production facilities into complexes. The development of this approach was influenced to some extent by works [3, 19, 24, 25, 26, 28, 30].

1. Statement of the Problem

Determining the structure of a complex ordinarily depends on numerous factors. The production relations among sectors, which differ in their direct impact on the development of particular production facilities, significantly influence the structure. It is wise to include in the complex only those types of production which have the closest production ties. Similarity of raw materials for the production facilities being joined into the complex and satisfying identical or mutually replaceable needs for output of the complex are very important also. The existence of groups of related industrial processes can also provide the foundation for joining primary production facilities into a complex. This creates a favorable opportunity for improving the technologies themselves.

The influence of the primary goals of development of production on the structure of the complex should be noted specially. A number of primary production facilities can be joined into a complex on the basis of common goals such as maximum satisfaction of certain ultimate demands, providing the entire system of primary production facilities with fuel, raw and processed materials, elements of fixed capital, and the like,

insuring environmental protection, defense capability, and others. Finally, the socioeconomic aspects, for example bringing the way of life of the rural and urban populations closer, improving working conditions, and developing particular economic regions and cities, also establish a basis for joining production facilities into a complex.

All factors must be given full consideration to identify the optimal structure. The efficiency of determining the structure depends significantly on this; it is advisable to determine the structure from the results of optimization of the development of the system of production facilities as a whole. The index of efficiency may be, for example, the value of the overall national economic criterion of optimality. Unfortunately, this method of evaluating the efficiency of determining the structure of complexes, while clear in theory, involves significant practical difficulties.

The basic idea of the approach suggested here for devising a practically substantiated structure for complexes with due regard for factors that influence it is as follows: Suppose that we have been able to single out from a given system of primary production facilities nonintersecting groups each of which could be the basis of the particular complex. Hereafter we will call these groups of production facilities the nuclei of the complexes. The methodology described in [3] or [30] can be used to shape the nuclei.

It is apparent that the set of nuclei of the complexes do not have to encompass the entire system of primary production facilities. There will remain some whose place in the complexes will be difficult to determine in advance. We will call these primary production facilities alternative. For each alternative production facility the problem of its inclusion in one of two complexes is solved. A complex may include several alternative production facilities, and for each of them the possibility of inclusion and noninclusion in the complex is reviewed.

It is most convenient to search for the solution to the problem of distribution of the entire set of alternative production facilities to the complexes by planning a certain number of practically acceptable and mutually exclusive variations of associating primary production facilities for each complex. These variations have a common nucleus and differ from one another by the types and number of alternative production facilities.

The most valuable thing in the variant method of describing the structure of a complex is that its nucleus and the set of alternative production facilities being considered can be shaped with due regard for the influence of factors that are not subject to formal description. The variant approach permits combining two processes: construction of the set of variations of the structure of each complex and choosing one variation from the entire set for each complex considering the factors that allow quantitative assessment.

It seems wise to single out the closeness of production ties, which are characterized by the size of flows of output among primary production facilities, from the entire set of factors that influence determination of the structure and are subject to quantitative assessment. It is evident that when the primary production facilities use more output within the complex and less of this output is shipped away, the complex will be more independent and self-sufficient. Therefore, the matrix of output flows permits a quantitative evaluation of the variations of the structure of the complex. Because the sum of all output flows of the interrelationship matrix is a constant quantity, the magnitude of flows of output within the complex only may be used as the criterion for choosing a variation. Other approaches to quantitative assessment of variations of the structure of complexes are also possible [25, 26, 29, 30].

If the nuclei of the complexes are varied during calculations, different structures will be obtained every time. It is obviously advisable to stop with that practically acceptable list of complexes and that structure of them where the value of the variant selection criterion is best. The following section gives a mathematical formulation of this problem.

2. Description of the Model

Suppose that a certain non-empty finite set of I numbers of i primary production facilities is given. Suppose $\bar{K}$ is a non-empty finite set of nuclei of future complexes, $\bar{K} = \{1, \ldots, K\}$, and for each complex k there is a finite set of N_k variants of the structure, $N_k = \{1, \ldots, V_k\}$. Each variant v of the structure of complex k is characterized by a set of numbers of primary production facilities $I_{kv} \subset I$.

We will call the set of I_k numbers of primary production facilities which are common to all variations of the complex the nucleus of the complex k, where none of these production facilities are included in the composition of other complexes $\hat{I}_k = \bigcap_{v \in N_k} I_{kv}$ and $\hat{I}_k \cap \hat{I}_r = \varnothing,\ k, r \in \bar{K}$.
We will call all those primary production facilities which are not included in the composition of the nucleus of any of the complexes under consideration alternative facilities. We will designate the set of numbers of alternative production facilities as $\check{I} = I \setminus \bigcup_{k \in \bar{K}} \hat{I}_k$.

Suppose we have given a subdivision of set $\check{I}$ into subsets of numbers of alternative production facilities $\check{I}_k$ for each complex k in such a way that $\bigcup_{k \in \bar{K}} \check{I}_k = \check{I}$, where there are pairs of complexes for which $\check{I}_k \cup \check{I}_r \neq \varnothing$, $k, r \in \bar{K}$. Continuing, we construct a set of numbers of alternative production facilities $\check{I}_{kv}$ such that $\check{I}_k = \bigcup_{v \in N_k} \check{I}_{kv}$ for each variation v of complex k. The set $\check{I}_{kv}$ can also be represented as the aggregate of numbers of primary production facilities of variation v of complex k which differ from its nucleus, that is $\check{I}_{kv} = I_{kv}/\hat{I}_k$.

All sets of variations for joining primary production facilities into complexes are fed to the problem at once and each variation is either accepted or rejected. During formalization this variant formulation makes it necessary to consider the Boolean variables δ_{kv}. Because the variations of one complex are mutually exclusive, only one of the numbers δ_{kv} can be equal to one for complex k and all the rest are zeros. The variation for which $\delta_{kv} = 1$ is adopted for consideration and the rest are set aside.

The conditions of discreteness in selection of variations of complex k can be described by the system of relations

$$\sum_{v \in V_k} \delta_{kv} = 1, \; k \in \bar{K}, \tag{1}$$

$$\delta_{kv} \geq 0 - \text{whole numbers.}$$

Conditions (1) do not insure the absence of contradiction in joint consideration of the variations. For example, it may prove that a certain primary production facility is included in the composition of several complexes or that for the chosen variations the set of primary production facilities does not encompass all of them.

To avoid these problems let us consider the set of different paths of joining variations. That is what we will call the aggregate that contains one variation for each complex. Therefore, each path consists of a number of variations equal to the number of complexes, and the number of paths

$$\prod_{k \in \bar{K}} V_k.$$

Not every path of joining variations is permissible. Each projected variation ordinarily consists of a nucleus and a number of alternative production facilities. The nuclei of the complexes by definition do not overlap. This cannot be said of the sets of alternative production facilities of the complexes. If a certain primary production facility has been assigned to the alternative category for at least one pair of complexes, there will be plan variations containing this facility in each of them. It is natural for the entire aggregate of complexes to assume as permissible that way of joining variations for which these conditions are met simultaneously:

$$\bigcup_{k=1}^{K} I_{kv_k} = I, \tag{2}$$

that is, the sum of nuclei and the set of alternative production facilities of the very same path form an initial set of primary production facilities

$$I_{kv} \cap I_{rw} = \varnothing, \tag{3}$$

that is, in one path the variations of the structure of different complexes do not have primary production facilities of the same name.

Let us set in correspondence to each path the product of the intensities δ_{kv} of use of the variations that form this path

$$\prod_{k=1}^{K} \delta_{kv_k}, \quad 1 \leqslant v_k \leqslant V_k.$$

If some way is impermissible from the standpoint of the conditions formulated above, the corresponding product should be made equal to zero. It follows from this that at least one of the magnitudes of δ_{kv} in the given product should be equal to zero. This means, in turn, that the corresponding variation of complex k cannot be considered together with the others that form this path. But if the magnitude of some product is set equal to one this illustrates that the way is permissible.

Thus, the permissibility of a path is written, in formal terms

$$\prod_{k=1}^{K} \delta_{kv_k} = \begin{cases} \text{if (2) and (3) are correct at the same time,} \\ \text{in the opposite case, } 1 \leqslant v_k \leqslant V_k. \end{cases} \tag{4}$$

We will use f^{kv} to designate the magnitude of a certain index of the effectiveness of selecting variation v of the structure of complex k. Then the problem of identifying the optimal structure of complexes consists in finding the extreme value of function

$$F = \sum_{k,v} f^{kv} \delta_{kv}$$

where conditions (1) and (4) are met. For example, if the criterion for selecting planned variations is maximization of the magnitude of output flows within the complex, then

$$f^{kv} = \sum_{i,j \in I_{kv}} a_{ij}^{kv},$$

where a_{ij}^{kv} is the non-negative magnitude of the flow of output from sector i to sector j, which is included in variation v for the formation of the structure of complex k.

Of course, the final solution to the problem of determining the structure of complexes involves more than just optimizing this discrete model. It can work as a tool for making multiple optimization calculations for the purpose of obtaining a certain set of possible proposals for the list of complexes and their structure. The final choice of practically acceptable structures may be done by experts or by a series of formal characteristics.

The multiplicity of calculations on the problem formulated above presupposes development of a fairly reliable and fast-working algorithm for solving the problem and a program that embodies this algorithm.

3. Description of the Algorithm

The idea of the algorithm to solve the whole-number problem formulated above involved successively cutting away pairs of variations which obviously cannot be included in any of the ways of forming the structure of the complexes, then constructing a set of permissible paths, and choosing from this set the one that is best from the standpoint of the criterion.

Step 1. Construction of the matrix of permissible interrelationships among variations.

Let us construct a matrix $T=\|t_{k\nu}^{r\mu}\|,\ k,r\in K,\ \nu\in N_k,\ \mu\in N_r$ consisting of zeros and ones. The pair of indexes k and v is the code for a line of this matrix and the pair of indexes are and μ are the code for a column. Ones in line (k, v) of matrix T indicate variations of complexes which can be considered together with variation ν of complex k, while ones in column (g, μ) indicate variations that may be considered together with variation μ of complex r. Therefore, matrix T is symmetrical relative to the main diagonal.

On the basis of the conditions of permissibility, in the pairs it is possible to consider together only those variations which belong to different complexes, are included in the composition of complexes that have common alternative production facilities, and have no common alternative production facilities.

Therefore, $t_{k\nu}^{r\mu}=1$ where the following conditions are met simultaneously:

$$1)\ k\neq r,$$
$$2)\ \bar{I}_k\cap\bar{I}_r\neq\varnothing,$$
$$3)\ \bar{I}_{k\nu}\cap\bar{I}_{r\mu}=\varnothing.$$

If even one of these conditions is not met $t_{k\nu}^{r\mu}=0$.

However, the impermissibility of particular pairs of variations represented by matrix T does not yet mean that all the possible associations of these pairs are impermissible in a particular way of considering the variations together for all complexes. With matrix T we were simply able to sharply narrow the set of pairs of variations on whose basis it is suggested that permissible ways of forming the structure of the complexes be constructed.

Step 2. This involves determination of the permissible paths. Using matrix T let us consider the entire set of pathsof joining the variations (one variation for each complex). The process of constructing a path on the basis of T is fairly simple and can be described as follows.

To maintain the common grounds of the reasoning, we will take, for example, the first one in the first line of T. We determine its coordinates as (k, v) and (r, μ). Further in T we find the line with parameters (r, μ), take one of the ones in it, and determine the parameter of the column in which it stands. Then we again find the line in T with the parameters of the column of the second one. On this line we take one of the ones and continue in this way until we reach the (K-1) one located on the line corresponding to the last complex K.

Therefore, each path is constructed so that the coordinates of the ones of the path have linkages. The number of the line of each consecutive one of the path is equal to the number of the column of the preceding one. It is not difficult to determine that the sets of paths constructed will be invariant relative to the procedure for going around the complexes, which means that the process of constructing the paths can be begun from any one in any line of T. Moreover, each one of matrix T will be "involved" in at least one path.

This method of constructing paths makes it possible to encompass the entire aggregate of paths which can be derived from matrix T, with each of them satisfying (1). However, each path constructed will not meet the conditions of permissibility (4), so they are checked. In this way the set of permissible paths for the problem is determined.

Step 3. The final step of the algorithm is to choose from the set of permissible paths that one which has the best value of target function F. This is the path that determines the planned variations for which the structure of associating primary production facilities into complexes is optimal.

We should observe that the paths of associating variations may have gaps which arise in the case where the entire set of complexes may be broken into groups in such a way that no complex of the group has common alternative production facilities with any other complex of the other groups. The paths will have the number of gaps corresponding to the number of distinct groups in this sense. The existence of gaps in a path illustrates, in its turn, that the problem breaks down into a series of distinct subproblems for each of which the algorithm presented is realized.

The algorithm described is finite because it is based on a sequential sorting of all possible paths of formation of the structure of the complexes.

A. K. Pitelin and L. P. Dotsenko, associates of the Central Mathematical Economic Institute of the Academy of Sciences USSR undertook the development of a standard COMPLEX program in the language Fortran-IV. This program utilizes the algorithm described. The program has two parts. One of the parts constructs the permissible paths of formation of the structure of the complexes and the second computes the values of the magnitudes of the internal interrelationships of the

production facilities included in complex k in conformity with the permissible variation v of its formation. The basic characteristic of the program is that the condition of "completeness"

$$\bigcup_k I_{k_v k} = I, \quad v_k \in N_k$$

is tested for only a certain part of a path, not for the path formed all the way to the end. For example, suppose that one variation apiece is taken from this given common number for half of the complexes. If it proves that the variations of the remaining complexes contain production facilities which do not complement those included in the selected variations for the first half of the complexes before initial set I, it is obviously senseless to consider all possible paths using the selected variations. In this case, they will not meet the conditions of "completeness." This procedure sharply cuts the number of paths considered and generally increases the efficiency of the work of the program.

Experiments run on YeS 1030 computers gave completely satisfactory results. The calculations were aimed at identifying multisectorial economic complexes in the national economy and use the report intersectorial balance of production and distribution of output in the USSR economy for 1972 as the matrix of interrelationships [31]. Detailed economic analysis of the results of the calculations would be a subject for a special study. Here we will only briefly describe one of the experiments in order to illustrate the work of the algorithms.

The initial data for the experiment was formed as follows. First the nuclei of the future complexes were constructed according to the given system of sectors. The sectors were joined into nuclei both by informal characteristics (common raw materials, production of identical, mutually replaceable final products, similarity of industrial processes, conformity in basic purposes of development) and on the basis of the magnitude of the flow of sectorial output by itself and of one of the sectors of the nucleus. This magnitude was taken as at least 50 percent of the total volume of output produced by the sector. The final list and composition of nuclei is given in Table 1 below.

The sectors which form the nuclei (there are 59 of them) make it possible to give general names to the production complexes: timber, machine building, agroindustrial, chemical, fuel-energy, metallurgical, construction, and transportation

Twenty-four sectors, that is 29 percent of the total number, were not included in the composition of the nuclei and formed the set of alternative sectors.*

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* Three sectors were excluded from the experiment (all agriculture; trade and public catering, procurement, and material-technical supply and marketing; other sectors of material production).

Table 1.*

(a) Комплекс	(b) Номера отраслей, образующих ядра комплексов	(c) Номера альтернативных отраслей
Лесной (1)	47, 48, 49, 50, 51, 52, 83	22
Машиностроительный (2)	15, 18, 19, 25, 32, 34, 36, 37	12, 13, 14, 16, 17, 20, 21, 22, 23, 24, 26, 27, 28, 29, 30, 31, 33, 35
Аграрно-промышленный (3)	61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 81, 82	23, 24, 31, 42
Химический (4)	38, 39, 40, 41, 43, 44, 45, 46	2, 6, 7, 8, 20, 21, 42
Топливно-энергетический (5)	5, 9, 10, 11	2, 6, 7, 8, 12, 13, 14, 20
Металлургический (6)	1, 4	2, 3, 14, 16, 17, 20, 35
Строительный (7)	53, 54, 55, 56, 57, 58, 59, 60, 79	3, 14, 26, 27, 28, 33, 35
Транспортный (8)	84	26, 27, 29, 30

Key: (a) Complex;
(b) Numbers of the sectors that form the nuclei of the complexes;
(c) Numbers of the alternative sectors;
(1) Timber;
(2) Machine building;
(3) Agroindustrial;
(4) Chemical;
(5) Fuel-energy;
(6) Metallurgical;
(7) Construction;
(8) Transportation.

* The numbering of the sectors is taken from the report intersectorial balance of production and distribution of output of the USSR for 1972 [31].

The next step in planning initial information involved breaking down the entire set of alternative sectors by complexes. In this case consideration was given to the same unformalized characteristics for assigning a sector to one of the complexes as were used in planning the nuclei, only in the case of the alternative sectors there was not sufficient certainty in considering each of the characteristics to assign the sector a particular complex. Therefore, each of them may be ascribed to one of two or more complexes. The results of breaking the alternative sectors down by complexes are also presented in Table 1 above.

Then mutually exclusive variations for joining the sectors into complexes were designed. During this four conditions were observed:

Table 2. (The symbol * signifies the set of numbers of sectors that form the nucleii of the corresponding complexes)

Варианты структуры комплексов (a)	Комплексы (Complexes)							
	лесной (b)	машиностроительный (c)	аграрно-промышленный (d)	химический (e)	топливно-энергетический (f)	металлургический (g)	строительный (h)	транспортный (i)
I	•	•	•	•	•	•	•	•
II	•, 22	•, 12	•, 23	•, 2	•, 2	•, 2	•, 3	•, 26
III	–	•, 13	•, 24	•, 6	•, 6	•, 3	•, 14	•, 27
IV	–	•, 14	•, 31	•, 7	•, 7	•, 14	•, 26	•, 29
V	–	•, 17	•, 42	•, 8	•, 8	•, 16	•, 27	•, 30
VI	–	•, 20	•, 23, 24	•, 20	•, 12	•, 17	•, 28	•, 26, 27
VII	–	•, 21	•, 31, 42	•, 21	•, 13	•, 20	•, 33	•, 29, 30
VIII	–	•, 22	•, 23, 24, 31, 42	•, 42	•, 14	•, 35	•, 35	•, 26, 27, 29
IX	–	•, 23	•, 24, 31	•, 2, 6, 7, 8	•, 20	•, 2, 3	•, 3, 14	•, 26, 27, 30
X	–	•, 24	•, 23, 42	•, 6, 7, 8	•, 2, 6, 7, 8	•, 2, 3, 14	•, 26, 27, 28	•, 27, 29, 30
XI	–	•, 26	–	•, 20, 21	•, 6, 7, 8	•, 2, 3, 14, 16	•, 3, 14, 26, 27, 28	•, 26, 27, 29, 30
XII	–	•, 27	–	•, 2, 6, 7, 8, 42	•, 12, 13, 14	•, 2, 3, 14, 16, 17	•, 26, 27, 28	–
XIII	–	•, 28	–	•, 20, 21, 42	•, 12, 13, 14, 20	•, 2, 3, 14, 16, 17, 35	•, 2, 6, 7, 27, 28, 33, 35	–
XIV	–	•, 29	–	•, 2, 6, 7, 8, 20, 21	•, 2, 6, 7, 8, 12, 13	•, 2, 17, 20	•, 3, 14, 26, 27, 28, 33, 35	–
XV	–	•, 30	–	–	•, 2, 6, 7, 8, 12, 13, 14, 20	•, 2, 3, 14, 16, 17, 20, 35	–	–
XVI	–	–	–	–	–	–	–	–
XVII	–	•, 33	–	–	–	–	–	–
XVIII	–	•, 35	–	–	–	–	–	–
XIX	–	•, 12, 13	–	–	–	–	–	–
XX	–	•, 30, 31, 12–14, 23	–	–	–	–	–	–
XXI	–	•, 12–14, 16, 17, 20–24, 26–31, 33–35	–	–	–	–	–	–
XXII	–	•, 16, 17, 20–24, 26–28, 33–35	–	–	–	–	–	–

Key: (a) Variations of the Structure of the Complexes;
(b) Timber;
(c) Machine Building;
(d) Agroindustrial;
(e) Chemical;
(f) Fuel-Energy;
(g) Metallurgical;
(h) Construction;
(i) Transportation.

1) each variation contains the nucleus of the complex; 2) one variation contains only the nucleus of the complex; 3) among the variations must be variations that contain one, two, three, and so on alternative sectors of the complex and differ from one another by containing at least one of them; 4) one variation included must contain all the alternative sectors of the complex.

In general, it would be possible for each complex to "automatically" construct $M_k = \sum_{p=0}^{N_k} C^p_{N_k}$ variations where

k is the number of the complex, N_k is the number of alternative sectors of complex k, p is a variable index, and $C^p{}_{N_k}$ is the number of combinations of N_k and p. In practice, however, there is no need for this because among the "automatically" planned variations will be ones that differ little from one another and others which are not worth considering for a priori reasons. For the timber complex two variations were planned, for the machine building complex 22, agroindustrial — 8, chemical — 14, fuel-energy — 15, metallurgical — 15, construction — 14, and transportation — 11. Table 2 shows the possible variation structuring of the initial system of sectors.

This completed the planning of initial data for the experimental example. Maximizing the magnitude of flows of output within the complexes was used as the criterion for selection of variations. The algorithm described above and the program that realized it made it possible to carry out the entire experimental calculation in six minutes. This illustrates the possibility of using the algorithm and program to perform multiple practical calculations with acceptable time expenditures.

As a result we found the following variations of formation of the structure of complexes to be optimal (see Table 2): timber — I; machine building — XXI; agroindustrial — II; chemical — XII, fuel-energy — I; metallurgical — I; construction — II; transportation — I.

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